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PROJECT FILE

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30 September 1964

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PE PI-624

MEMORANDUM FOR THE RECORD

SUBJECT: Determination of a Transfer Function for the Coherent Light Enlarger

BACKGROUND

The evaluation and acceptance of the coherent light enlarger constructed under contract by [] is the one problem remaining before delivery. In a recent trip to [] the difficulties of such an evaluation were discussed with their engineers. The discussions pointed up the lack of a precise method for determining the instrument's performance characteristics. Resolution measurements, using the classic three-bar target, will not suffice for this enlarger because they will not test the flatness of the pass-band.

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In view of these difficulties an attack on the problem was deferred until additional studies were made. The results of these studies and several meetings with our technical consultant [] are summarized in this memorandum. This memorandum also proposes a method for assessment of the modulation transfer function for the coherent light enlarger which, at this writing, is the technique which defines system performance with the least ambiguity.

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THE DIFFICULTY OF EVALUATION

One of the significant measures of optical system performance is the specification of its modulation transfer function. This records the differential attenuation of an object in its passage to an image, on a spatial frequency basis. In an electronic amplifier, these characteristics are designated as "frequency response," and the optical interpretation is analogous, with one important difference -- electrical systems are linear in amplitude and phase, while optical systems are linear only in the squared modulus of the electric vector, or intensity.

A coherent optical system is linear in amplitude and phase, while the measureable quantity is light intensity. Such a system is therefore necessarily non-linear in intensity. It can be shown that this results in the dependence of the transfer function on the object being imaged. The details of this and subsequent statements may be verified by reference to "Theory of Partial Coherence," by Berand and Parrent, Prentice-Hall, 1964, Chapter 8. Because of this object-dependence it is

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impossible to determine a unique result for the ratio of sine-wave resolution limits for coherent and incoherent light. Further, because we are physically limited to measurements of intensity, it is simply not possible to compare any resolution limits without ambiguity.

Specification of an object and its image in terms of mutual intensity provides a linear analysis, regardless of the degree of coherence. While this fact is significant, it effects no result useful for present purposes, since transfer functions are not defined in terms of mutual intensity. Measurements of this latter quantity are seldom straightforward.

In view of all these considerations the problem is one of choosing an evaluation technique which is the least ambiguous -- one in which the amplitude distribution differs minimally from its intensity distribution. Such a condition prevails when the square of a quantity equals its square root. It occurs for two numbers, zero and unity. A method utilizing this principle will now be described.

DETERMINATION OF MODULATION TRANSFER FUNCTION

A Ronchi ruling is to be used as an object. The ratio of line to space preferably should not be unity, since the even spectral orders will be missing, with correspondingly fewer sampling points. It is necessary that the lines be opaque and the spaces clear, so that the amplitude and intensity relationships mentioned in the previous section appertain. The period is determined by comparator measurements or any other reliable technique. For the system under consideration it is suggested that the ruling have a period between 20 and 40 lines/mm with at least seven orders visible in the Fraunhofer pattern. This crenelate pattern must now be decomposed into its Fourier components. It can be readily effected by illuminating the pattern with a laser and measuring the intensity maxima in the far field. The strength of each spectral order need only be measured relative to the central order. No absolute intensity measurements are necessary.

The ruling is now inserted in object space and allowed to pass to the image plane, during which process its components become attenuated by the system's modulation transfer function. It will be necessary to use a fluid gate to eliminate phase variations in the object. The degree to which these phase variations are eliminated and the transmittance limits of the ruling approach zero and unity, directly affect the ambiguity of the resultant transfer function.

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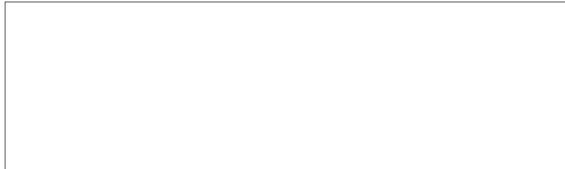
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Ordinarily, the image is assessed through microphotometric methods or by recording on a photographic material which is then subjected to microphotometric evaluation. There is a third alternative available which utilizes the property of coherence, and eliminates the necessity for photographic recording. When an additional lens(es) of appropriate focal length is placed behind the image plane, the image is Fourier transformed into another Fraunhofer pattern. This now resolves the image into its frequency components, spaced according to system magnification and the focal length of the transforming lens(es). In the particular case under consideration the pattern should be smaller because the enlarger is operating at 4x magnification. The transforming lens should not materially affect the results. The intensity of these diffraction maxima are now measured photometrically relative to the central order. The ratio of these relative measurements to those previously determined for the ruling outside the coherent light enlarger, is the modulation transfer function at each component frequency.

The mathematical details are certainly not trivial, and for reasons of time have not been worked out by me. I have also not had time nor the necessary equipment to verify this method experimentally. Conversations with our consultant lead me to believe in the essential correctness of the technique. This memorandum or those parts pertaining to his problem should be forwarded to the contractor for his possible use. I will be willing to discuss this with him and work out some of the details should he so desire.

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Chief, Exploratory Development Laboratory Branch
P&DS

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MEMORANDUM OF CALL

Date 17 Sep 64 Time 1540

TO-

☒ YOU

TELEPHONE: Number of code

☒ PLEASE CALL ☐ WAITING TO SEE YOU
☐ WILL CALL AGAIN ☐ WISHES AN APPOINTMENT
☐ RETURNING YOUR CALL
☐ IS REFERRED TO YOU BY:

LEFT THIS MESSAGE: Re the coherent light
enlarger built in
Contractor has a few bucks left
and an idea as to what he
can do to get them. He

Received By- Russ

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